Sustainability and PVD: What can we do?

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Presentation outline

- Motivation and introduction
- Considerations:
    - Energy consumption
    - Efficient use of resources
    - Material and samples waste
- Conclusions

Motivation and introduction

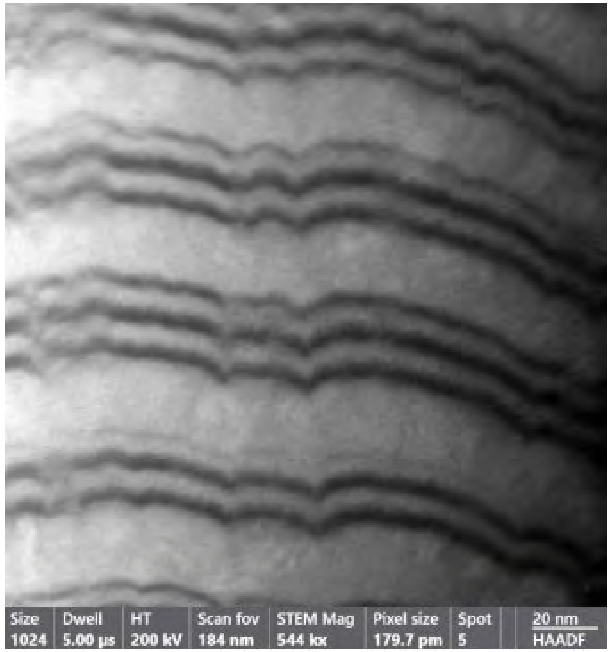
Physical Vapor Deposition (PVD)

https://www.stockholmresilience.org/research/research-news/2017-02-28-contributions-to-agenda-2030.html

Physical Vapor Deposition (PVD)

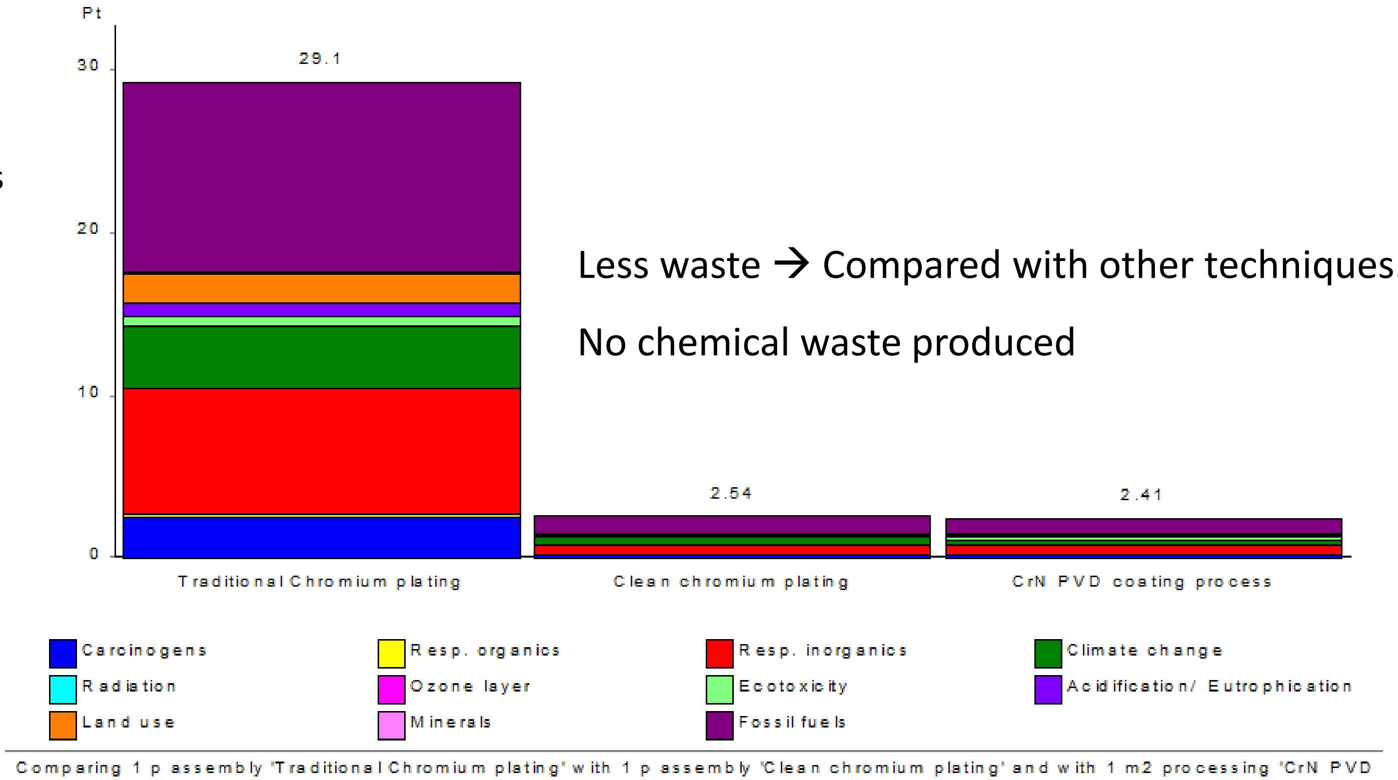
- Physical Vapor Deposition (PVD) is a coating process that is well known to be environmentally friendly.
- PVD: Thin film, less material
  - Thickness as thin as 5 nm
  - Multilayer capability → Combination of functionalities

TEM images : Sputtering coating



20 nm

Comparison of piston rings coating processes



Less waste → Compared with other techniques.

No chemical waste produced

What can we do to improve?

- FUTURE:
  - Surface engineering
  - Research and Development

- PRESENT:
  - Choosing the correct deposition technology
  - Moving into more efficient processes

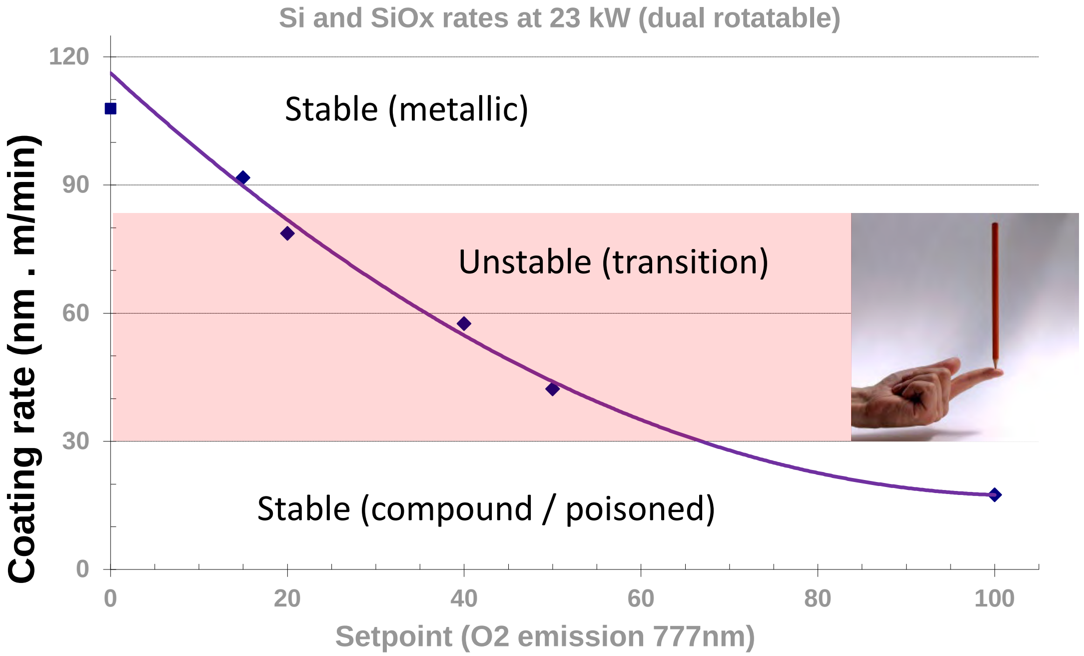
Considerations

Energy consumption

Energy reduction by reactive feedback control

Why feedback controllers are used for reactive sputtering:

- Deposition Rate
- Process stability



- Stable poisoned deposition rate - 18 nm/min
- Unstable transition deposition rate - 60 nm/min

Large area coating applying reactive feedback control:

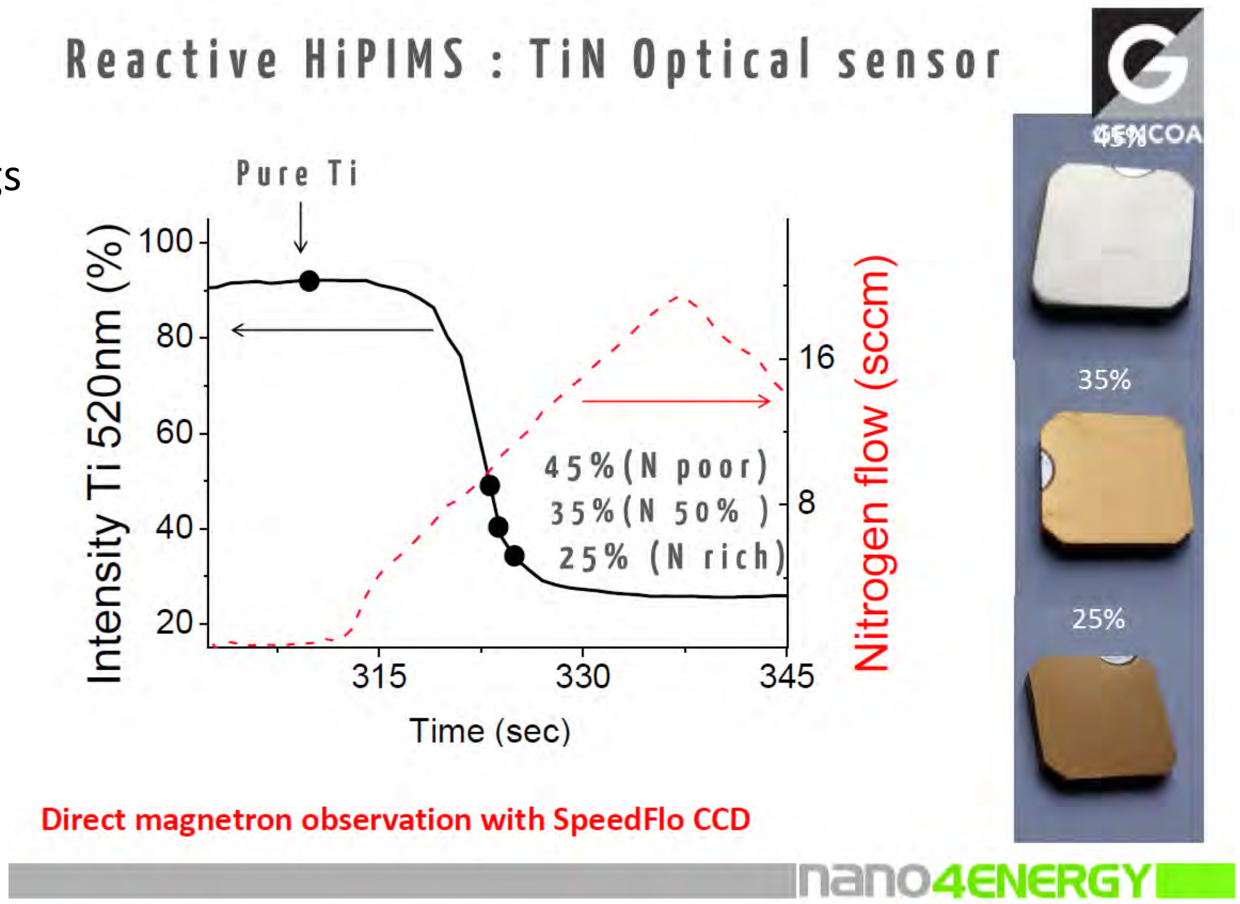
Deposition rate improvement **x3**

Cathodes power reduction from **200kW down to 60kW**

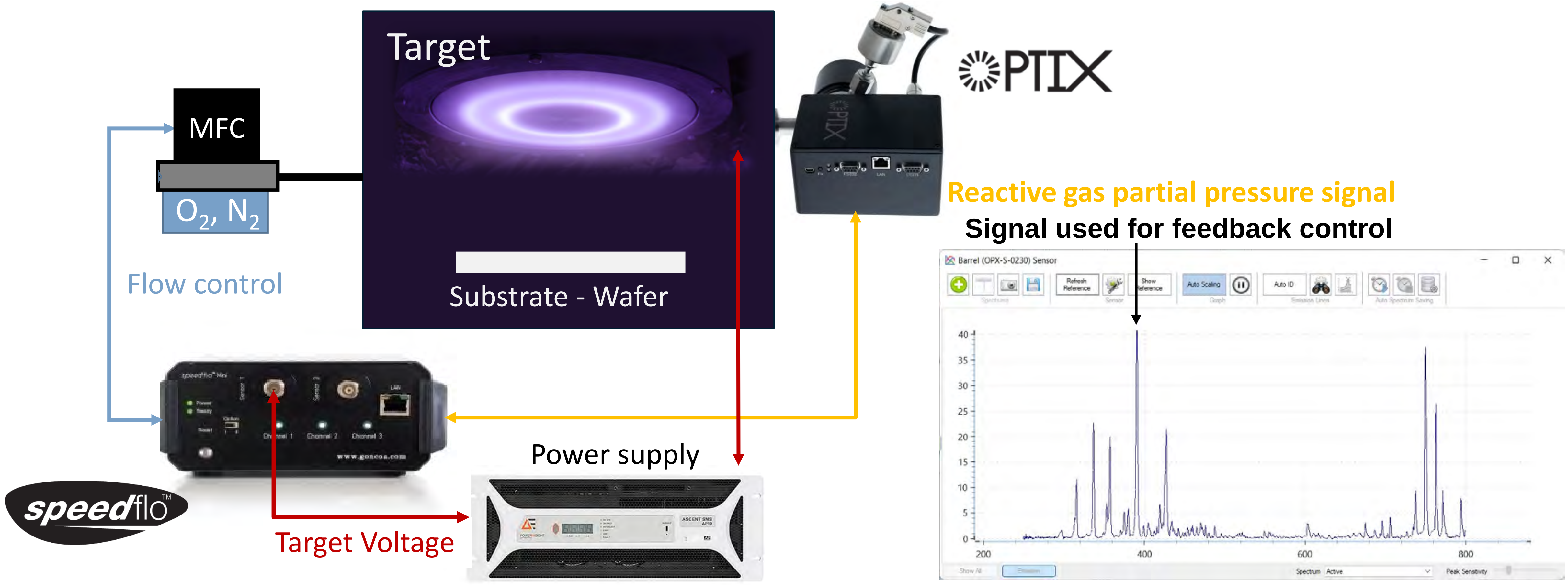
Energy reduction by reactive feedback control

Why feedback controllers are used for reactive sputtering:

- Stoichiometry
- High reproducibility for industrial coatings
- Reduce on material and samples waste



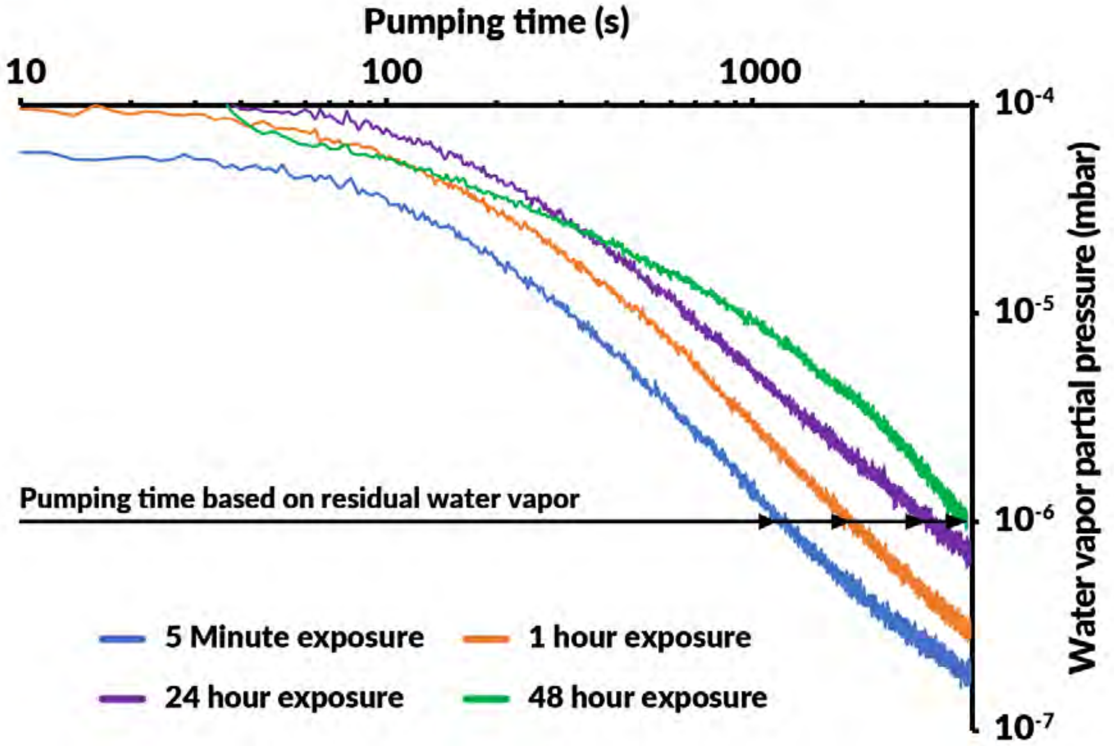
Energy reduction by reactive feedback control



Reducing coating time → Energy saving!

Monitoring moisture outgassing from powder stock Hot Isostatic Pressing

- The duration of outgassing should be linked to removing the outgas problem via sensing
- Typically 50% time and energy can be saved with outgas monitoring
- Quality assurance, traceability, and safety specifications can be assured
- Canister leak check



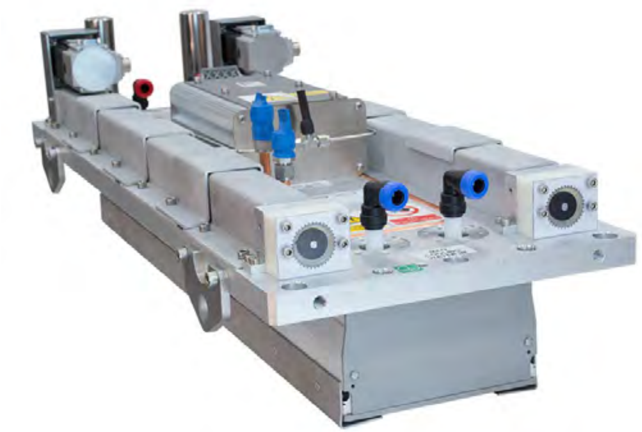
Reducing pumping time → Energy saving!

Modelling, simulation and design

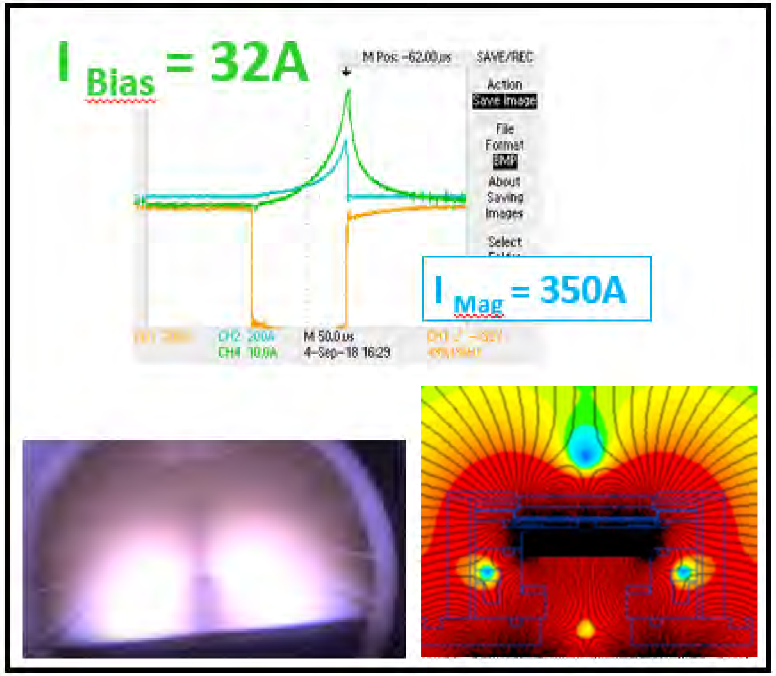
Tailoring coating ion assistance

Variable field shape and balance/unbalance during the coating process:

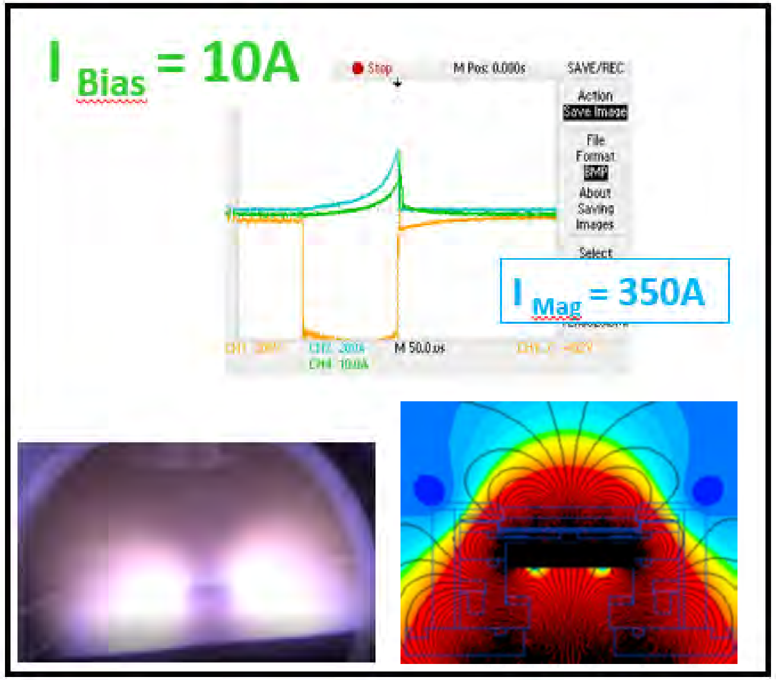
2 functionality – 1 cathode



Strong UBM



Balanced



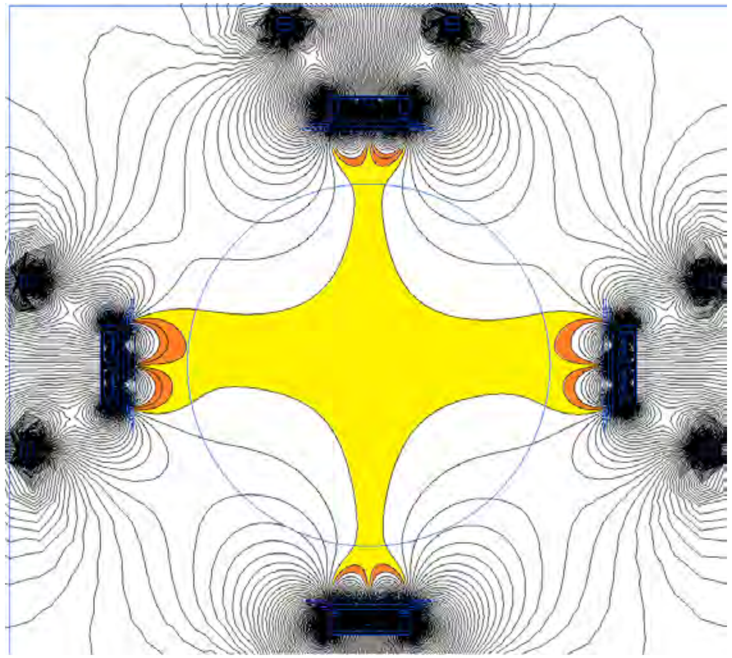
Reducing development coating runs → Energy saving!

Modelling and simulation

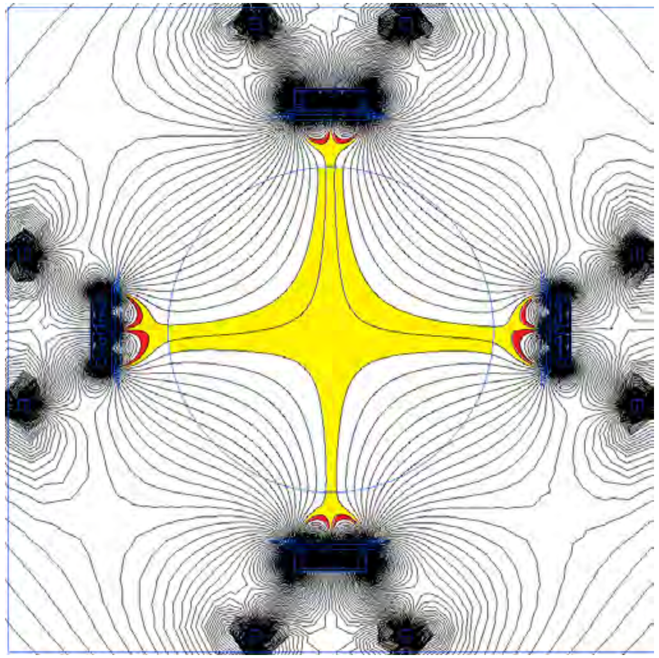
- Improving and re-purposing existing equipment and systems

From low energy deposition to high energy deposition set-up

1 system – Multiple functions



VTER in Balanced position



VTER in Unbalanced position

Reducing development coating runs → Energy saving!

Considerations

Efficient use of resources

Optimum magnetic designs

Big box coater

Small box coater

Roll-to-Roll

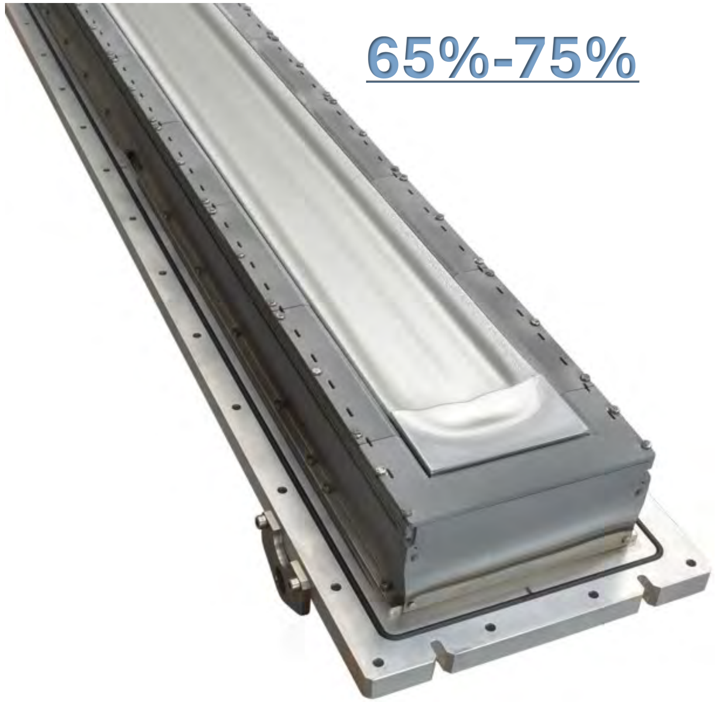
In-line system

Reducing material waste → Target material saving!

High target use

Rectangular XH magnetron

65%-75%

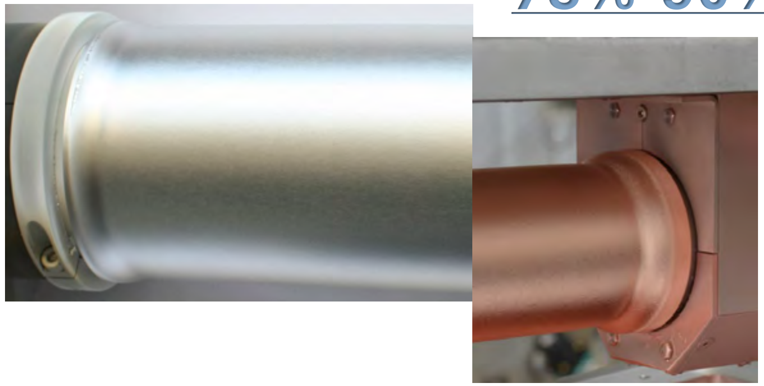


FFE- Full Face Erosion

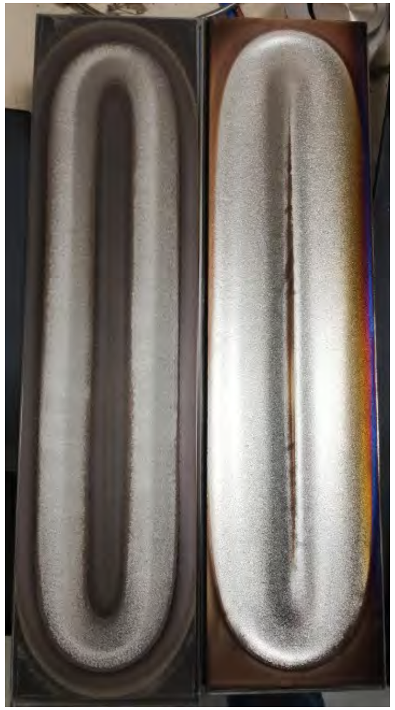
50%-70%

Rotatable cathodes

75%-90%



HY- High Yield



40%-50%

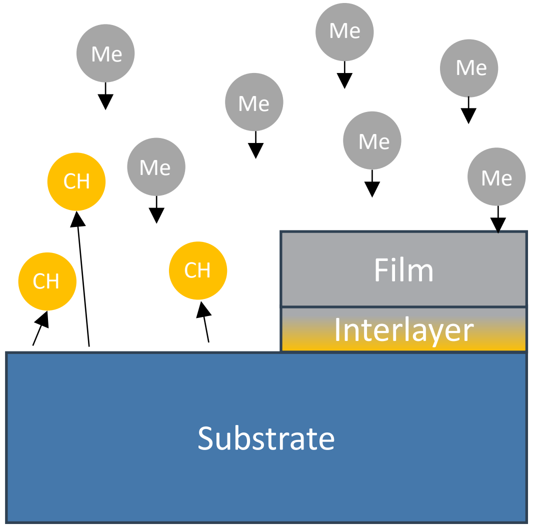
Less target material waste → Target material saving!

Considerations

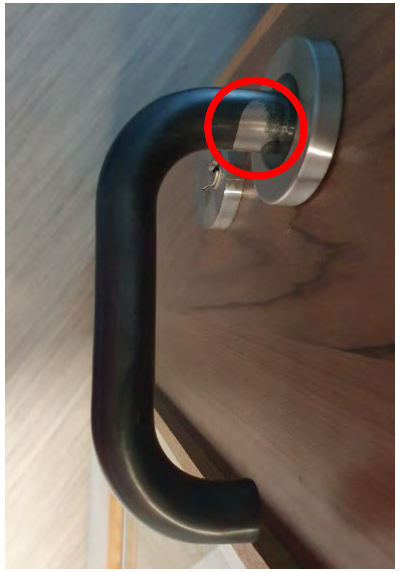
Material and samples waste

High quality control

- Outgassing of materials in vacuum can have a detrimental effect on subsequent processing
- EG during vacuum coating - Durability, Defects, Delamination…

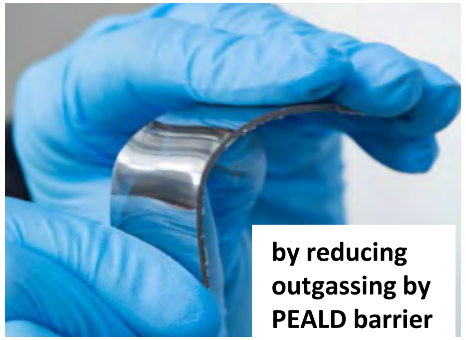


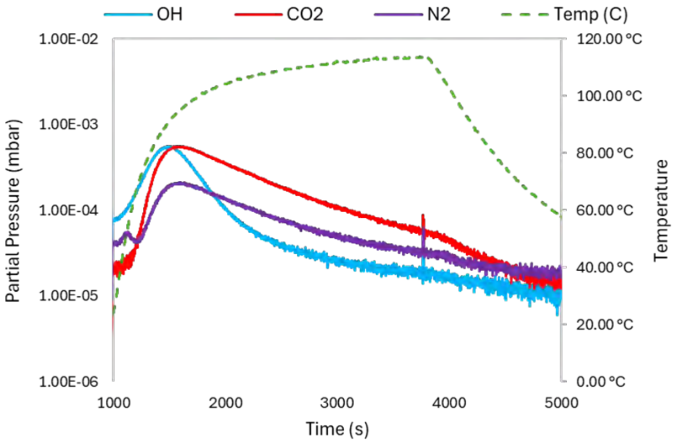
Oil outgassing



Poor adhesion of Ti on PMMA

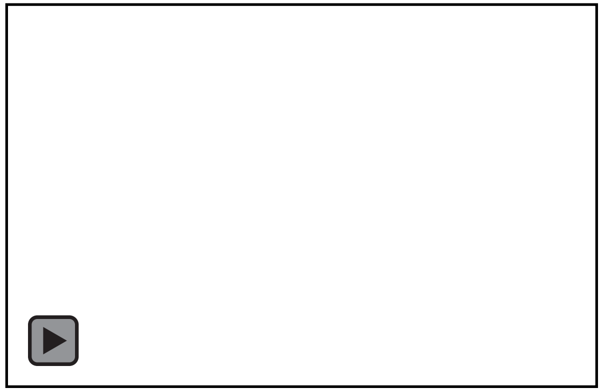
Good adhesion of Ti



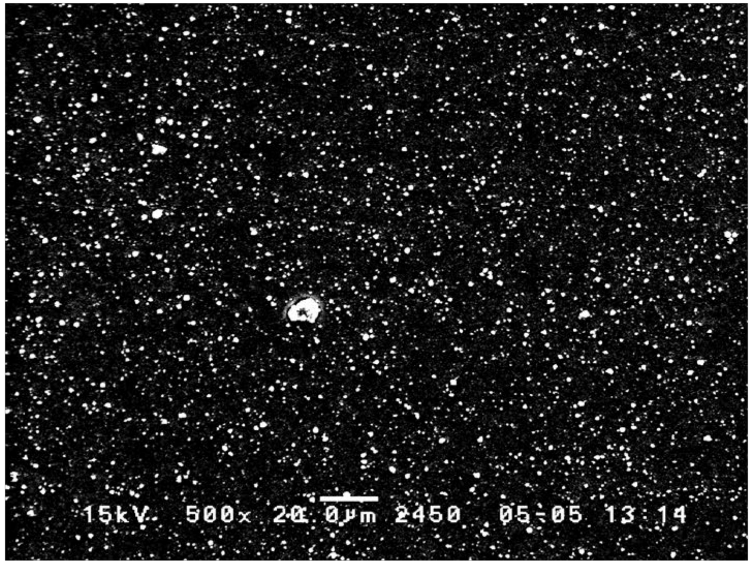


Monitoring of process quality → Material saving!

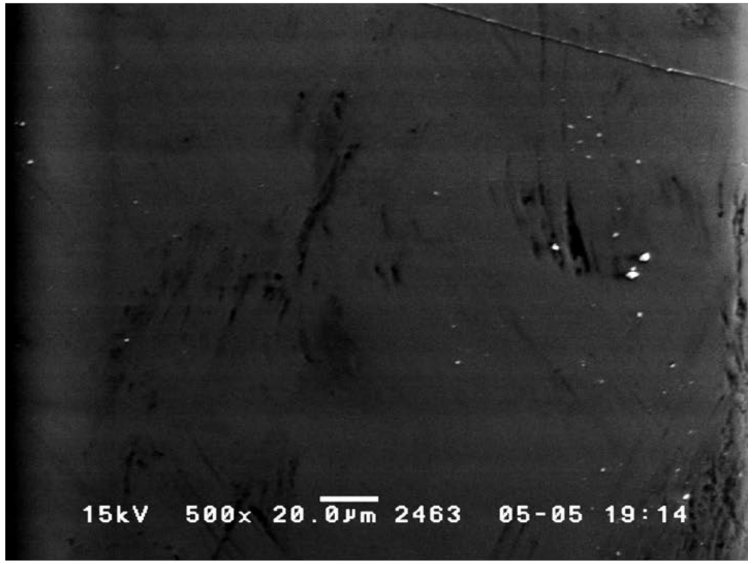
Defects reduction



20% set point



60% set point



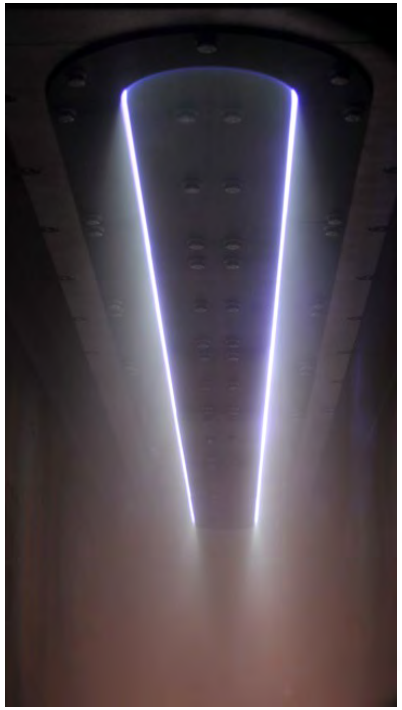
- Optix signal used for control
- Samples produced under 20% control (on the left) show high defect count when viewed under SEM
- In the image on the right a 60% set point was chosen – important to tune reactive process to correct poisoning point!

Reducing defects → Material saving!

Reducing coating failure

Presented at ICCG 2016

Plasma sources for good adhesion



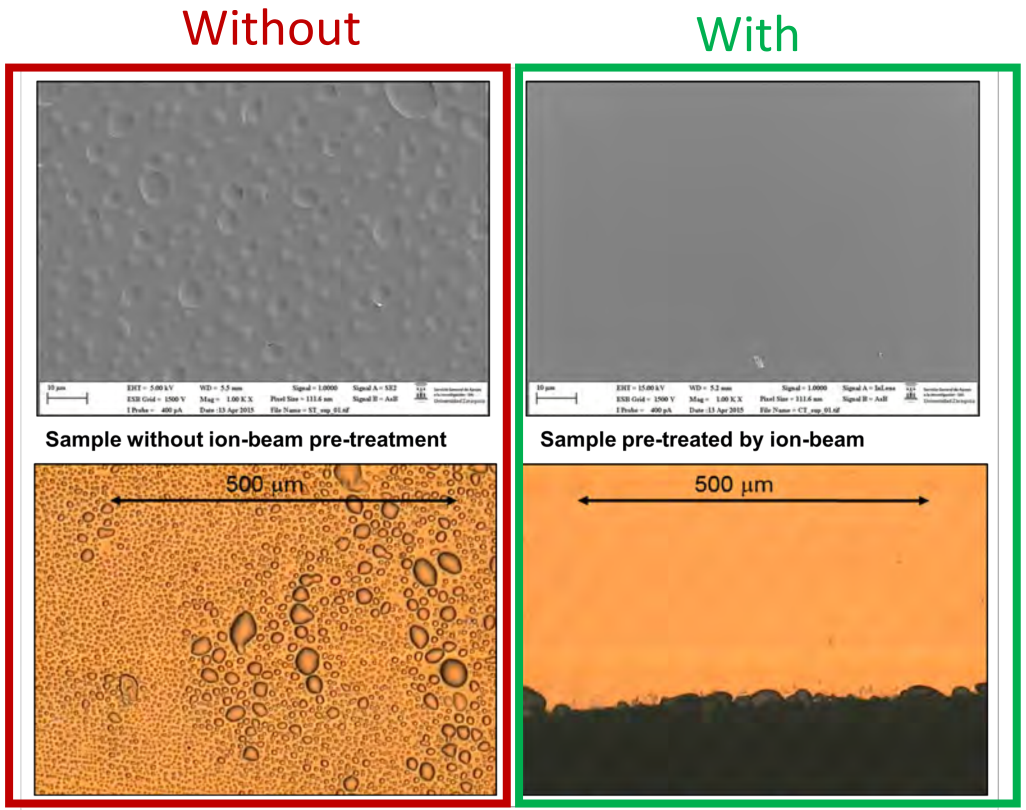


Figure 5: Top: SEM images of untreated and pre-treated coated, tempered glass panes. Without the ion source, the coating shows many defects and blisters whereas the ion source has improved the coating adhesion, that no blisters could be observed.
Bottom: Optical microscopy for the different treated samples. Blisters are visible for the untreated glass. To observe the smooth surface of the pre-treated sample, the image had to be taken at the end of the deposition to have a visibly change in the coating.

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Reducing coating failure → Material saving!

Conclusions

- We have already available resources, tools and vacuum technologies that could have a huge impact on the sustainability of the coating processes.
- We should continue moving forward and invest on research for alternative and more sustainable processes and coating technology but without forgetting what we already have.

✓ Decrease the energy consumption on every step of the process

✓ Have a more efficient use of resources that have both an economic and human impact

✓ Reduce the material and samples waste

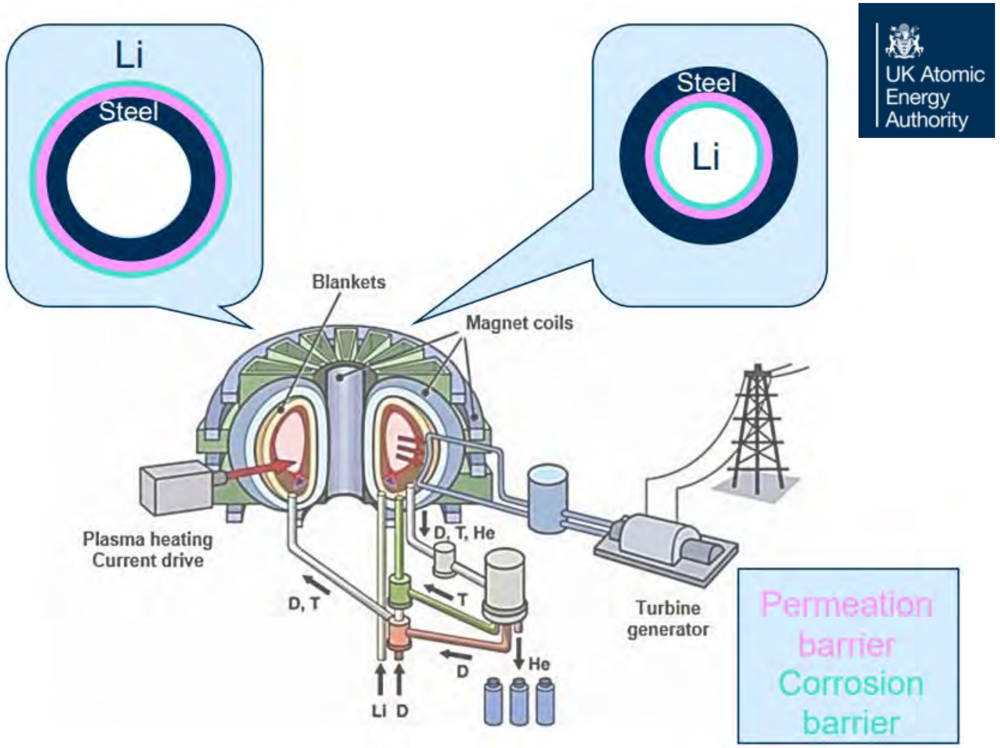
Sustainable future for PVD coatings?

- Coatings for fusion application → we need the action now to build the supply chain for the Fusion Industry

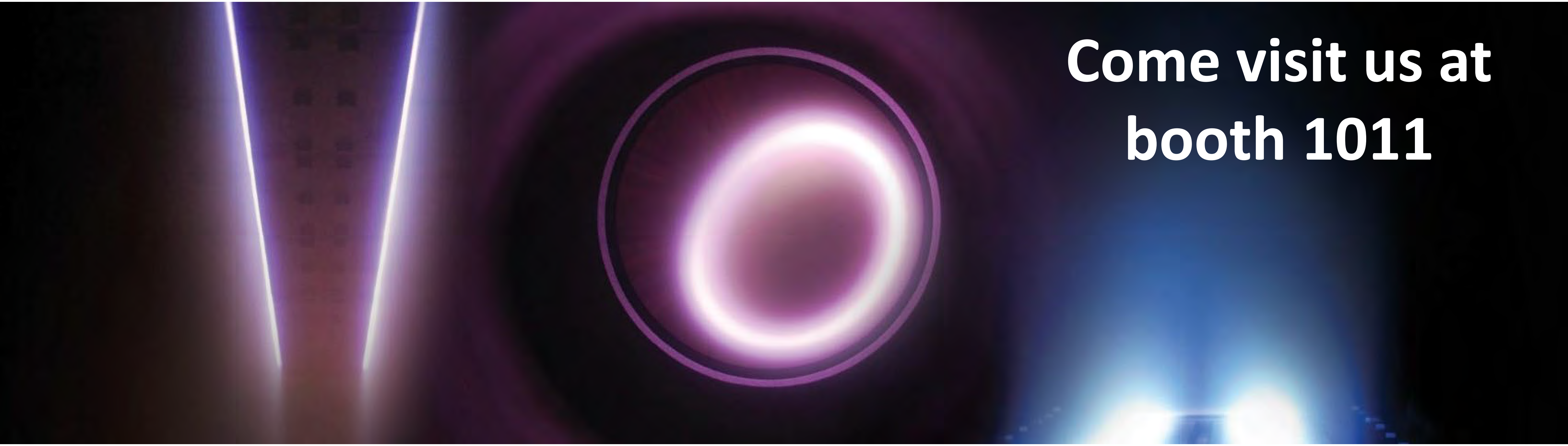
- <u>Permeation barrier coating</u>
  To prevent losses of tritium in the structural material (reactor walls, tubes,..) → Radioactivity issues, T fuel cycle

- <u>Corrosion barrier coating</u>
  To protect surfaces from exposure to high temperature and aggressive environment
  → Highly reactive molten metals (Li,..) are used for cooling and T breeding

Multi-layer *multi-functional* coatings



Thank you



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